EXHIBIT A
Support for Claims 1-28

Reproduced below, are portions of the specification of the present Application that are examples of support in the present Application for each limitation of Claims 1-28 delineated below. This list is not intended to be exhaustive.

I. Support for Claim 1

A. ***A method for determining an axial force acting on each one of a plurality of roller cones on a roller cone drill bit during drilling, comprising:***

1. The present invention uses a single element force-cutting relationship in order to develop the total force-cutting relationship of a cone and of an entire roller cone bit. Looking at **Figure 1**, each tooth, shown on the right side, can be thought of as composed of a collection of elements, such as are shown on the left side. Each element used in the present invention has a square cross section with area S_e (its cross-section on the x-y plane) and length L_e (along the z axis). The force-cutting relationship for this single element may be described by:

$$F_{ze} = k_e * \sigma * S_e \quad (1)$$
$$F_{xe} = \mu_x * F_{ze} \quad (2)$$
$$F_{ye} = \mu_y * F_{ze} \quad (3)$$

where F_{ze} is the normal force and F_{xe}, F_{ye} are side forces, respectively, σ is the compressive strength, S_e the cutting depth and k_e, μ_x and μ_y are coefficient associated with formation properties. These coefficients may be determined by lab test. A tooth or an insert can always be divided into several elements. Therefore, the total force on a tooth can be obtained by integrating equation (1) to (3). The single element force model used in the invention has significant advantage over the single tooth or single insert model used in most of the publications. The only way to obtain a force model is by lab test. There are many types of inserts used today for roller cone bit depending on the rock type drilled. If the single insert force model is used, a lot of tests have to be done and this is very difficult if not impossible. By using the element force model, only a few tests may be enough because any kind of insert or tooth can be always divided into elements. In other words, one element model may be applied to all kinds of inserts or teeth.

After having the single element force model, the next step is to determine the interaction between inserts and the formation drilled. This step involves the determination of the tooth kinematics (local) from the bit and cone kinematics (global) as described below.

(1) The bit kinematics is described by bit rotation speed, Ω=RPM (revolutions per minute), and the rate of penetration, ROP. Both RPM and ROP may be considered as constant or as function with time.

(2) The cone kinematics is described by cone rotational speed. Each cone may have its own speed. The initial value is calculated from the bit geometric parameters or just estimated from experiment. In the calculation the cone speed may be changed based on the torque acting on the cone.

(3) At the initial time, t0, the hole bottom is considered as a plane and is meshed into small grids. The tooth is also meshed into grids (single elements). At any time t, the position of a tooth in space is fully determined. If the tooth is in interaction with the hole bottom, the hole bottom is updated and the cutting depth for each cutting element is calculated and the forces acting on the elements are obtained.

(4) The element forces are integrated into tooth forces, the tooth forces are integrated into cone forces, the cone forces are transferred into bearing forces and the bearing forces are integrated into bit forces. *See Present Application, Page 11, line 7 through Page 12, line 17.*

B. ***calculating, from a geometry of cutting elements on each of the roller cones and an earth formation being drilled by the drill bit, an axial force acting on each of the cutting elements;***

1. The present invention uses a single element force-cutting relationship in order to develop the total force-cutting relationship of a cone and of an entire roller cone bit. Looking at **Figure 1**, each tooth, shown on the right side, can be thought of as composed of a collection of elements, such as are shown on the left side. Each element used in the present invention has a square cross section with area S_e (its cross-section on the x-y plane) and length L_e (along the z axis). The force-cutting relationship for this single element may be described by:

$$F_{ze} = k_e * \sigma * S_e \qquad (1)$$

$$F_{xe} = \mu_x * F_{ze} \qquad (2)$$

$$F_{ye} = \mu_y * F_{ze} \qquad (3)$$

where F_{ze} is the normal force and F_{xe}, F_{ye} are side forces, respectively, σ is the compressive strength, S_e the cutting depth and k_e, μ_x and μ_y are coefficient associated with formation properties. These coefficients may be determined by lab test. A tooth or an insert can always be divided into several elements. Therefore, the total force on a tooth can be obtained by integrating equation (1) to (3). The single element force model used in the invention has significant advantage over the single tooth or single insert model used in most of the publications. The only way to obtain a force model is by lab test. There are many types of inserts used today for roller cone bit depending on the rock type drilled. If the single insert force model is used, a lot of tests have to be done and this is very difficult if not impossible. By using the element force model, only a few tests may be enough because any kind of insert or tooth can be always divided into elements. In other words, one element model may be applied to all kinds of inserts or teeth. *See Present Application, Page 11, lines 7-29.*

C. ***incrementally rotating the bit and recalculating the axial forces acting on each of the cutting elements;***

1. (1) The bit kinematics is described by bit rotation speed, Ω=RPM (revolutions per minute), and the rate of penetration, ROP. Both RPM and ROP may be considered as constant or as function with time.

(2) The cone kinematics is described by cone rotational speed. Each cone may have its own speed. The initial value is calculated from the bit geometric parameters or just estimated from experiment. In the calculation the cone speed may be changed based on the torque acting on the cone.

(3) At the initial time, t0, the hole bottom is considered as a plane and is meshed into small grids. The tooth is also meshed into grids (single elements). At any time t, the position of a tooth in space is fully determined. If the tooth is in interaction with the hole bottom, the hole bottom is updated and the cutting depth for each cutting element is calculated and the forces acting on the elements are obtained. *See Present Application, Page 12, lines 3-14.*

D. ***repeating the incrementally rotating and recalculating for a selected number of incremental rotations; and***

1. (5) After the bit is fully drilled into the rock, these forces are recorded at each time step. A period time usually at least 10 seconds is simulated. The average forces may be considered as static forces and are used for evaluation of the balance condition of the cutting structure. *See Present Application, Page 12, lines 18-21.*

E. ***combining the axial force acting on the cutting elements on each one of the roller cones.***

1. (4) The element forces are integrated into tooth forces, the tooth forces are integrated into cone forces, the cone forces are transferred into bearing forces and the bearing forces are integrated into bit forces. *See Present Application, Page 12, lines 15-17.*

II. Support for Claim 2

A. ***The method as defined in Claim 1 wherein the axial force acting on each of the cutting elements totals an axial force applied to the drill bit.***

1. The present invention uses a single element force-cutting relationship in order to develop the total force-cutting relationship of a cone and of an entire roller cone bit. *See Present Application, Page 11, lines 7-8.*

2. See Paragraph I(E)(1) above. *See Present Application, Page 12, lines 15-17.*

3. where ωi (i = 1, 2, 3) is defined by ωi = WOBi / WOB * 100 %, WOBi is the weight on bit taken by cone i. ηi is defined by ηi = Fzi / ΣFzi * 100 % with Fzi being the i-th cone axial force. *See Present Application, Page 13, lines 2-4.*

III. Support for Claim 3

A. ***The method of Claim 2 further comprising determining an axial force acting on each of the cutting elements with respect to a predetermined relationship between depth of penetration and axial force applied for the cutting element geometry and the earth formation.***

1. The present invention uses a single element force-cutting relationship in order to develop the total force-cutting relationship of a cone and of an entire roller cone bit. Looking at **Figure 1**, each tooth, shown on the right side, can be thought of as composed of a collection of elements, such as are shown on the left side. Each element used in the present invention has a square cross section with area S_e (its cross-section on the x-y plane) and length L_e (along the z axis). The force-cutting relationship for this single element may be described by:

$$F_{ze} = k_e * \sigma * S_e \qquad (1)$$
$$F_{xe} = \mu_x * F_{ze} \qquad (2)$$
$$F_{ye} = \mu_y * F_{ze} \qquad (3)$$

where F_{ze} is the normal force and F_{xe}, F_{ye} are side forces, respectively, σ is the compressive strength, S_e the cutting depth and k_e, μ_x and μ_y are coefficient associated with formation properties. These coefficients may be determined by lab test. A tooth or an insert can always be divided into several elements. Therefore, the total force on a tooth can be obtained by integrating equation (1) to (3). The single element force model used in the invention has significant advantage over the single tooth or single insert model used in most of the publications. The only way to obtain a force model is by lab test. *See Present Application, Page 11, lines 7-24.*

IV. Support for Claim 4

A. ***The method of Claim 3 wherein the predetermined relationship is determined by laboratory experiment.***

1. See Paragraph III(A)(1) above. *See Present Application 11, lines 7-24.*

V. Support for Claim 5

A. ***A method for determining a volume of formation cut by each one of a plurality of roller cones on a drill bit drilling in earth formations, comprising:***

1. It is not difficult to calculate the volumes removed by each row and the volume matrix may have the form:

$$V = [\ V_{ij}\ ],\quad i = 1,2,3;\ j = 1,2,3,4,\ldots \qquad (8)$$

where i represent the cone number and j the row number. *See Present Application, Page 14, lines 12-16.*

2. Let V_1, V_2 and V_3 be the volume removed by cone 1,2 and 3, respectively. *See Present Application, Page 15 line 1.*

B. ***selecting bit design parameters, comprising at least a geometry of a cutting element on the drill bit;***

1. The first step in the optimization procedure is to choose the design variables. Consider a cone of a steel tooth bit as shown in **Figure 3**. The cone has three rows. For the sake of simplicity, the journal angle, the offset and the cone profile will be fixed and will not be as design variables. Therefore the only design variables for a row are the crest length, Lc, the radial position of the center of the crest length, Rc, and the tooth angles, α and β. Therefore, the number of design variables is 4 times of the total number of rows on a bit. *See Present Application, Page 13, line 28 through Page 14, line 2.*

C. ***selecting an earth formation;***

1. $$F_{ze} = k_e * \sigma * S_e \qquad (1)$$

$$F_{xe} = \mu_x * F_{ze} \qquad (2)$$

$$F_{ye} = \mu_y * F_{ze} \qquad (3)$$

where F_{ze} is the normal force and F_{xe}, F_{ye} are side forces, respectively, σ is the compressive strength, S_e the cutting depth and k_e, μ_x and μ_y are coefficient associated with formation properties. These coefficients may be determined by lab test. A tooth or an insert can always be divided into several elements. Therefore, the total force on a tooth can be obtained by integrating equation (1) to (3). The single element force model used in the invention has significant advantage over the single tooth or single insert model used in most of the publications. The only way to obtain a force model is by lab test. There are many types of inserts used today for roller cone bit depending on the rock type drilled. *See Present Application, Page 11, lines 14-25.*

D. ***calculating from the selected bit design parameters and the selected earth formation, parameters for a crater formed when each one of a plurality of cutting elements on each of the roller cones contacts the earth formation, the parameters including at least a volume of the crater;***

1. (d) calculating the volume of formation displaced by a crater enlargement parameter function. *See '805 Application, Page 27, lines 8-9.*

2. *See '466 Provisional, Flowchart.*

E. ***incrementally rotating the bit, and repeating the calculating of the crater parameters for a selected number of incremental rotations; and***

1. See Paragraph I(C)(1) above. *See Present Application, Page 12, lines 3-14.*

2. **Figure 6** shows the flowchart of the optimization procedure. The procedure begins by reading the bit geometry and other operational parameters. The forces on the teeth, cones, bearings, and bit are then calculated. Once the forces are known, they are compared, and if they are balanced, then the design is optimized. If

the forces are not balanced, then the optimization must occur. Objectives, constraints, design variables and their bounds (maximum and minimum allowed values) are defined, and the variables are altered to conform to the new objectives. Once the new objectives are met, the new geometric parameters are used to re-design the bit, and the forces are again calculated and checked for balance. This process is repeated until the desired force balance is achieved. *See Present Application, Page 15, line 26 through Page 16, line 4.*

F. ***combining the volume of each crater formed by each of the cutting elements on each of the roller cones to determine the volume of formation cut by each of the roller cones.***

1. The volume matrix has the final form:

$$V_b\,(i,j) = K_v(i,j) * V(i,j) = f_v\,(L_c, R_c, \alpha, \beta) \qquad (10)$$

Let V_1, V_2 and V_3 be the volume removed by cone 1,2 and 3, respectively. *See Present Application, Page 14, line 29 through Page 15, line 1.*

2. (a) calculating the volume of formation cut by each tooth on each cutting structure; (b) calculating the volume of formation cut by each cutting structure per revolution of the drill bit; *See Present Application, Page 17, lines 17-20.*

VI. Support for Claim 6

A. ***The method as defined in Claim 5 wherein the volume of each of the craters is determined by: determining an axial force on each of the cutting elements;***

1. $F_{ze} = k_e * \sigma * S_e \qquad (1)$

$$F_{xe} = \mu_x * F_{ze} \qquad (2)$$

$$F_{ye} = \mu_y * F_{ze} \qquad (3)$$

where F_{ze} is the normal force and F_{xe}, F_{ye} are side forces, respectively, σ is the compressive strength, S_e the cutting depth and k_e, μ_x and μ_y are coefficient associated with formation properties. These coefficients may be determined by lab test. A tooth or an insert can always be divided into several elements. Therefore, the total force on a tooth can be obtained by integrating equation (1) to (3). The single element force model used in the invention has significant advantage over the single tooth or single insert model used in most of the publications. The only way to obtain a force model is by lab test. There are many types of inserts used today for roller cone bit depending on the rock type drilled. If the single insert force model is used, a lot of tests have to be done and this is very difficult if not impossible. By using the element force model, only a few tests may be enough because any kind of insert or tooth can be always divided into elements. In other words, one element model may be applied to all kinds of inserts or teeth.

After having the single element force model, the next step is to determine the interaction between inserts and the formation drilled. This step involves the

determination of the tooth kinematics (local) from the bit and cone kinematics (global) as described below. *See Present Application, Page 11, line 14 through Page 12, line 2.*

B. ***calculating, from the axial force on each of the cutting elements, an expected depth of penetration and projected area of contact between each of the cutting elements and the earth formation; and***

1. At any time t, the position of a tooth in space is fully determined. If the tooth is in interaction with the hole bottom, the hole bottom is updated and the cutting depth for each cutting element is calculated and the forces acting on the elements are obtained. *See Present Application, Page 12, lines 11-14.*

C. ***calculating the volume of each of the craters from the expected depth of penetration and projected area of contact.***

1. Suppose the bit has a cutting depth Δ in one bit revolution. It is not difficult to calculate the volumes removed by each row and the volume matrix may have the form:

$$V = [\ V_{ij}\ ],\quad i = 1,2,3;\ j = 1,2,3,4,\ldots \qquad (8)$$

where i represent the cone number and j the row number. *See Present Application, Page 14, lines 11-16.*

VII. Support for Claim 7

A. ***The method as defined in Claim 6 further wherein the axial force acting on each of the cutting elements totals an axial force applied to the drill bit.***

1. See Paragraph II(A)(1) above. *See Present Application, Page 11, lines 7-8.*

2. See Paragraph I(E)(1) above. *See Present Application, Page 12, lines 15-17.*

3. See Paragraph II(A)(3) above. *See Present Application, Page 13, lines 2-4.*

VIII. Support for Claim 8

A. ***The method of Claim 7 further comprising determining an axial force acting on each of the cutting elements with respect to a predetermined relationship between depth of penetration and axial force applied for the cutting element geometry and the earth formation.***

1. See Paragraph III(A)(1) above. *See Present Application 11, lines 7-24.*

IX. Support for Claim 9

A. ***The method of Claim 8 wherein the predetermined relationship is determined by laboratory experiment.***

1. See Paragraph III(A)(1) above. *See Present Application 11, lines 7-24.*

X. Support for Claim 10

A. ***A method for balancing axial forces acting on each one of a plurality of roller cones on a roller cone drill bit during drilling, comprising:***

1. The present application describes bit design procedures which provide optimization of downforce balancing as well as other parameters. *See Present Application, Page 7, line 32 through Page 8, line 2.*

2. The first step in the optimization procedure is to choose the design variables. Consider a cone of a steel tooth bit as shown in **Figure 3**. The cone has three rows. For the sake of simplicity, the journal angle, the offset and the cone profile will be fixed and will not be as design variables. Therefore the only design variables for a row are the crest length, Lc, the radial position of the center of the crest length, Rc, and the tooth angles, α and β. Therefore, the number of design variables is 4 times of the total number of rows on a bit.

The second step in the optimization procedure is to define the objectives and express mathematically the objectives as function of design variables. According to equation (1), the force acting on an element is proportional to the rock volume removed by that element. This principle also applies to any tooth. Therefore, the objective is to let each cone remove the same amount of rock in one bit revolution. This is called volume balance or energy balance. The present inventor has found that an energy balanced bit will lead to force balanced in most cases. Consider **Figure 4** which shows the patterns cut by each cone on the hole bottom. The first rows of all three cones have overlap and the inner rows remove the rock independently. Suppose the bit has a cutting depth Δ in one bit revolution. It is not difficult to calculate the volumes removed by each row and the volume matrix may have the form:

$$V = [\ V_{ij}\ ],\quad i = 1,2,3;\ j = 1,2,3,4,\ldots \qquad (8)$$

where i represent the cone number and j the row number. For example, V_{32} is the element in the volume matrix representing the rock volume removed by the second row of the third cone. The elements V_{ij} of this matrix are all functions of the design variables.

In reality, the removed volume by each row depends not only on the above design variables, but also on the number of teeth on that row and the tracking condition. Therefore the volume matrix calculated in a 2D manner must be scaled. The scale matrix, K_v, may be obtained as follows.

$$K_v\,(i,j) = V_{3d0}\,(i,j)\,/\,V_{2d0}\,(i,j) \qquad (9)$$

where V_{3d0} is the volume matrix of the initial designed bit (before optimization). V_{3d0} is obtained from the rock bit computer program by simulate the bit drilling procedure at least 10 seconds. V_{2d0} is the volume matrix associated with the initial designed matrix and obtained using the 2D manner based on the bottom pattern shown in **Figure 4**. The volume matrix has the final form:

$$V_b\,(i,j) = K_v(i,j) * V(i,j) = f_v\,(L_c, R_c, \alpha, \beta) \qquad (10)$$

Let V_1, V_2 and V_3 be the volume removed by cone 1,2 and 3, respectively. For the energy balance, the objective function takes the following form:

$$Obj = (V_1\text{-}V_m)\hat{}2 + (V_2\text{ -}V_m)\hat{}2 + (V_3\text{ -}V_m)\hat{}2 \qquad (11)$$

where $V_m = (V_1 + V_2 + V_3)/3$;

The third step in the optimization procedure is to define the bounds of the design variables and the constraints. The lower and upper bounds of design variables can be determined by requirements on element strength and structural limitation. For example, the lower bound of a tooth crest length is determined by the tooth strength. The angle α and β may be limited to 0 ~ 45 degrees. One of the most important constraints is the interference between teeth on different cones. A minimum clearance between teeth surface must be kept. Consider **Figure 5** where cone profile is shown in a plane. A minimum clearance between tooth surfaces is required. This clearance can be expressed as a function of the design variables.

$$\Delta d = f_d\,(L_c, R_c, \alpha, \beta) \qquad (12)$$

Another constraint is the width of the uncut formation rings on bottom. The width of the uncut formation rings should be minimized or equalized in order to avoid the direct contact of cone surface to formation drilled. These constraints can be expressed as:

$$\Delta w_{min} <= \Delta wi = fw_i\,(L_c, R_c, \alpha, \beta) <= \Delta w_{max} \qquad (13)$$

There may be other constraints, for example, the minimum space between two neighbored rows on the same cone required by the mining process.

After having the objective function, the bounds and the constraints, the problem is simplified to a general nonlinear optimization problem with bounds and nonlinear constraints which can be solved by different methods. **Figure 6** shows the flowchart of the optimization procedure. The procedure begins by reading the bit geometry and other operational parameters. The forces on the teeth, cones, bearings, and bit are then calculated. Once the forces are known, they are compared, and if they are balanced, then the design is optimized. If the forces are not balanced, then the optimization must occur. Objectives, constraints, design variables and their bounds (maximum and minimum allowed values) are defined, and the variables are altered to conform to the new objectives. Once the new objectives are met, the new

geometric parameters are used to re-design the bit, and the forces are again calculated and checked for balance. This process is repeated until the desired force balance is achieved. *See Present Application, Page 13, line 28 through Page 16, line 4.*

B. ***calculating, from a geometry of cutting elements on each of the roller cones and an earth formation being drilled by the drill bit, an axial force acting on each of the cutting elements;***

1. See Paragraph I(B)(1) above. *See Present Application, Page 11, lines 7-29.*

C. ***incrementally rotating the bit and recalculating the axial forces acting on each of the cutting elements;***

1. See Paragraph I(C)(1) above. *See Present Application, Page 12, lines 3-14.*

D. ***repeating the incrementally rotating and recalculating for a selected number of incremental rotations;***

1. See Paragraph I(D)(1) above. *See Present Application, Page 12, lines 18-21.*

E. ***combining the axial force acting on the cutting elements on each one of the roller cones; and***

1. See Paragraph I(E)(1) above. *See Present Application, Page 12, lines 15-17.*

F. ***adjusting at least one bit design parameter, and repeating the calculating the axial force, incrementally rotating and combining the axial force, until a difference between the combined axial force on each one of the roller cones is less than a difference between the combined axial force determined prior to adjusting the at least one initial design parameter.***

1. With reference to **Figure 2**, the balance condition of a roller cone bit may be evaluated using the following criteria:

$$\text{Max}(\omega 1, \omega 2, \omega 3) - \text{Min}(\omega 1, \omega 2, \omega 3) <= \omega 0 \qquad (4)$$
$$\text{Max}(\eta 1, \eta 2, \eta 3) - \text{Min}(\eta 1, \eta 2, \eta 3) <= \eta 0 \qquad (5)$$
$$\text{Max}(\lambda 1, \lambda 2, \lambda 3) - \text{Max}(\lambda 1, \lambda 2, \lambda 3) <= \lambda 0 \qquad (6)$$
$$\xi = F_r / WOB * 100\ \% <= \xi 0 \qquad (7)$$

where ωi ($i = 1, 2, 3$) is defined by $\omega i = WOBi / WOB * 100\ \%$, WOBi is the weight on bit taken by cone i. ηi is defined by $\eta i = Fzi / \Sigma Fzi * 100\ \%$ with Fzi being the i-th cone axial force. And λi is defined by $\lambda i = Mzi / \Sigma Mzi * 100\ \%$ with Mzi being the i-th cone moment in the direction perpendicular to i-th cone axis. Finally ξ is the bit imbalance force ratio with F_r being the bit imbalance force. A bit is perfectly balanced if:

$\omega 1 = \omega 2 = \omega 3 = 33.333\ \%$ or $\omega 0 = 0.0\ \%$
$\eta 1 = \eta 2 = \eta 3 = 33.333\ \%$ or $\eta 0 = 0.0\ \%$
$\lambda 1 = \lambda 2 = \lambda 3 = 33.333\ \%$ or $\lambda 0 = 0.0\ \%$
$\xi = 0.0\ \%$

In most cases if $\omega 0$, $\eta 0$, $\lambda 0$, $\xi 0$ are controlled with some limitations, the bit is balanced. The values of $\omega 0$, $\eta 0$, $\lambda 0$, $\xi 0$ depend on bit size and bit type. *See Present Application, Page 12, line 27 through Page 13, line 13.*

2. Once the forces are known, they are compared, and if they are balanced, then the design is optimized. If the forces are not balanced, then the optimization must occur. Objectives, constraints, design variables and their bounds (maximum and minimum allowed values) are defined, and the variables are altered to conform to the new objectives. Once the new objectives are met, the new geometric parameters are used to re-design the bit, and the forces are again calculated and checked for balance. This process is repeated until the desired force balance is achieved. *See Present Application, Page 15, line 29 through Page 16, line 4.*

3. (d) adjusting at least one geometric parameter on the design of at least one cutting structure; (e) repeating steps (a) through (d) until approximately the same axial force is acting on each cutting structure. *See Present Application, Page 17, line 30 through Page 18, line 2.*

XI. Support for Claim 11

A. ***The method as defined in Claim 10 wherein the axial force acting on each of the cutting elements totals an axial force applied to the drill bit.***

1. See Paragraph II(A)(1) above. *See Present Application, Page 11, lines 7-8.*

2. See Paragraph I(E)(1) above. *See Present Application, Page 12, lines 15-17.*

3. See Paragraph II(A)(3) above. *See Present Application, Page 13, lines 2-4.*

XII. Support for Claim 12

A. ***The method of Claim 11 further comprising determining an axial force acting on each of the cutting elements with respect to a predetermined relationship between depth of penetration and axial force applied for the cutting element geometry and the earth formation.***

1. See Paragraph III(A)(1) above. *See Present Application 11, lines 7-24.*

XIII. Support for Claim 13

A. ***The method of Claim 12 wherein the predetermined relationship is determined by laboratory experiment.***

1. See Paragraph III(A)(1) above. *See Present Application 11, lines 7-24.*

XIV. Support for Claim 14

A. ***The method as defined in Claim 10 wherein the at least one bit design parameter comprises a number of cutting elements on at least one of the cones.***

1. Among these parameters, the teeth crest length, their positions on cones (row distribution on cone) and the number of teeth play a significant role. *See Present Application, Page 13, lines 22-23.*

XV. Support for Claim 15

A. ***The method as defined in Claim 10 wherein the at least one bit design parameter comprises a location of cutting elements on at least one of the cones.***

1. Among these parameters, the teeth crest length, their positions on cones (row distribution on cone) and the number of teeth play a significant role. *See Present Application, Page 13, lines 22-23.*

XVI. Support for Claim 16

A. ***A method for balancing a volume of formation cut by each one of a plurality of roller cones on a drill bit drilling in earth formations, comprising:***

1. The roller cone bit is energy balanced such that each of the cutting structures drill substantially equal volumes of formation. *See Present Application, Page 8, lines 20-21.*

2. Since the amount of formation removed by any tooth on a cutting structure is a function of the force imparted on the formation by the tooth, the volume of formation removed by a cutting structure is a direct function of the force applied to the cutting structure. By balancing the volume of formation removed by all cutting structures, force balancing is also achieved. *See Present Application, Page 16, lines 14-18.*

B. ***selecting bit design parameters, comprising at least a geometry of a cutting element on the drill bit;***

1. See Paragraph V(B)(1) above. *See Present Application, Page 13, line 28, through Page 14, line 2.*

C. ***selecting an earth formation;***

1. See Paragraph V(C)(1) above. *See Present Application, Page 11, lines 14-25.*

D. ***calculating from the selected bit design parameters and the selected earth formation, parameters for a crater formed when each one of a plurality of cutting elements on each of the roller cones contacts the earth formation, the parameters including at least a volume of the crater;***

1. See Paragraph V(D)(1) above. *See '805 Application, Page 27, lines 8-9.*

2. See Paragraph V(D)(2) above. *See '466 Provisional, Flowchart.*

E. ***incrementally rotating the bit, and repeating the calculating of the crater parameters for a selected number of incremental rotations;***

1. See Paragraph I(C)(1) above. *See Present Application, Page 12, lines 3-14.*

2. See Paragraph V(E)(2) above. *See Present Application, Page 15, line 26 through Page 16, line 4.*

F. ***combining the volume of each crater formed by each of the cutting elements on each of the roller cones to determine the volume of formation cut by each of the roller cones; and***

1. See Paragraph V(F)(1) above. *See Present Application, Page 14, line 29 through Page 15, line 1.*

2. See Paragraph V(F)(2) above. *See Present Application, Page 17, lines 17-20.*

G. ***adjusting at least one of the bit design parameters, and repeating the calculating the crater volume, incrementally rotating and combining the volume until a difference between the combined volume cut by each of the cones is less than the combined volume determined prior to the adjusting the at least one of the bit design parameters.***

1. See Paragraph X(F)(1) above. *See Present Application, Page 12, line 27 through Page 13, line 13.*

2. See Paragraph X(F)(2) above. *See Present Application, Page 15, line 29 through Page 16, line 4.*

3. See Paragraph X(F)(3) above. *See Present Application, Page 17, line 30 through Page 18, line 2.*

XVII. Support for Claim 17

A. ***The method as defined in Claim 16 wherein the volume of each of the craters is determined by: determining an axial force on each of the cutting elements;***

1. See Paragraph VI(A)(1) above. *See Present Application, Page 11, line 14 through Page 12, line 2.*

B. ***calculating, from the axial force on each of the cutting elements, an expected depth of penetration and projected area of contact between each of the cutting elements and the earth formation; and***

1. See Paragraph VI(B)(1) above. *See Present Application, Page 12, lines 11-14.*

C. ***calculating the volume of each of the craters from the expected depth of penetration and projected area of contact.***

1. See Paragraph VI(C)(1) above. *See Present Application, Page 14, lines 11-16.*

XVIII. Support for Claim 18

A. ***The method as defined in Claim 17 wherein the axial force acting on each of the cutting elements totals an axial force applied to the drill bit.***

1. See Paragraph II(A)(1) above. *See Present Application, Page 11, lines 7-8.*

2. See Paragraph I(E)(1) above. *See Present Application, Page 12, lines 15-17.*

3. See Paragraph II(A)(3) above. *See Present Application, Page 13, lines 2-4.*

XIX. Support for Claim 19

A. ***The method of Claim 18 further comprising determining an axial force acting on each of the cutting elements with respect to a predetermined relationship between depth of penetration and axial force applied for the cutting element geometry and the earth formation.***

1. See Paragraph III(A)(1) above. *See Present Application 11, lines 7-24.*

XX. Support for Claim 20

A. ***The method as defined in Claim 16 wherein the at least one bit design parameter comprises a number of cutting elements on at least one of the cones.***

1. See Paragraph XIV(A)(1) above. *See Present Application, Page 13, lines 22-23.*

XXI. Support for Claim 21

A. ***The method as defined in Claim 16 wherein the at least one bit design parameter comprises a location of cutting elements on at least one of the cones.***

1. See Paragraph XV(A)(1) above. *See Present Application, Page 13, lines 22-23.*

XXII. Support for Claim 22

A. ***A method for optimizing a design of a roller cone drill bit, comprising:***

1. Designer can optimize the design of roller cone drill bits within designer-chosen constraints. *See Present Application, Page 9, lines 11-12.*

B. ***simulating the bit drilling through a selected earth formation;***

1. (5) After the bit is fully drilled into the rock, these forces are recorded at each time step. A period time usually at least 10 seconds is simulated. *See Present Application, Page 12, lines 18-19.*

2. V_{3d0} is obtained from the rock bit computer program by simulate the bit drilling procedure at least 10 seconds. *See Present Application, Page 14, lines 25-27.*

C. ***adjusting at least one design parameter of the bit;***

1. (d) adjusting at least one geometric parameter on the design of at least one cutting structure; *See Present Application, Page 17, lines 21-23.*

D. ***repeating the simulating the bit drilling; and***

1. See Paragraph XXII(B)(1) above. *See Present Application, Page 12, lines 18-19.*

2. (e) repeating steps (a) through (d) until substantially the same volume of formation is cut by each of said cutting structures of said bit. *See Present Application, Page 17, lines 23-24..*

E. ***repeating the adjusting and simulating until an optimized design is determined.***

1. See Paragraph XXII(B)(1) above. *See Present Application, Page 12, lines 18-19.*

2. See Paragraph X(F)(2) above. *See Present Application, Page 15, line 29 through Page 16, line 4.*

3. See Paragraph XXII(D)(2) above. *See Present Application, Page 17, lines 23-24.*

XXIII. Support for Claim 23

A. ***The method as defined in Claim 22 wherein the at least one design parameter comprises a parameter selected from the group of a number of cutting elements on each one of a plurality of roller cones, cutting element type, and a number of rows of cutting elements on each one of the plurality of roller cones.***

1. Among these parameters, the teeth crest length, their positions on cones (row distribution on cone) and the number of teeth play a significant role. An increase in the size of any one parameter must of necessity result in the decrease or increase of one or more of the others. And in some cases design rules may be violated. Obviously the development of optimization procedure is absolutely necessary. *See Present Application, Page 13, lines 22-27.*

XXIV. Support for Claim 24

A. ***The method as defined in Claim 22 wherein the optimized design is determined when a rate of penetration of the bit through the selected earth formation is maximized.***

1. However for the bit manufacturer or bit designer it is necessary to know the teeth orientation angle on the cone coordinate, in order either to keep the elongate side of the tooth perpendicular to the scraping direction (for maximum cutting rate in softer formations) or to keep the elongate side of the tooth in line with the scraping direction (for durability in harder formations). *See '262 Patent, Column 9, lines 53-60.*

XXV. Support for Claim 25

A. ***The method as defined in Claim 22 wherein the optimized design is determined when axial force on the bit is substantially balanced between the roller cones.***

1. Once the forces are known, they are compared, and if they are balanced, then the design is optimized. *See Present Application, Page 15, lines 29-30.*

XXVI. Support for Claim 26

A. ***The method as defined in Claim 22 wherein the optimized design is determined when a volume of formation cut by the bit is substantially balanced between the roller cones.***

1. See Paragraph XXV(A)(1) above. *See Present Application, Page 15, lines 29-30.*

2. By balancing the volume of formation removed by all cutting structures, force balancing is also achieved. *See Present Application, Page 16, lines 17-18.*

XXVII. Support for Claim 27

A. ***The method as defined in Claim 22 wherein the simulating comprises: selecting bit design parameters;***

1. See Paragraph V(B)(1) above. *See Present Application, Page 13, line 28 through Page 14, line 2.*

B. ***selecting drilling parameters;***

1. After having the single element force model, the next step is to determine the interaction between inserts and the formation drilled. This step involves the determination of the tooth kinematics (local) from the bit and cone kinematics (global) as described below.

(1) The bit kinematics is described by bit rotation speed, Ω=RPM (revolutions per minute), and the rate of penetration, ROP. Both RPM and ROP may be considered as constant or as function with time.

(2) The cone kinematics is described by cone rotational speed. Each cone may have its own speed. The initial value is calculated from the bit geometric parameters or just estimated from experiment. In the calculation the cone speed may be changed based on the torque acting on the cone. *See Present Application, Page 11, line 30 through Page 12, line 9.*

C. ***selecting an earth formation to be represented as drilled;***

1. See Paragraph V(C)(1) above. *See Present Application, Page 11, lines 14-25.*

D. ***calculating from the selected parameters and the formation, parameters for a crater formed when one of a plurality of cutting elements on the bit contacts the earth formation, the cutting elements having known geometry;***

1. See Paragraph V(D)(1) above. *See '805 Application, Page 27, lines 8-9.*

2. See Paragraph V(D)(2) above. *See '466 Provisional, Flowchart.*

E. ***calculating a bottomhole geometry, wherein the crater is removed from a bottomhole surface;***

1. (3) At the initial time, t0, the hole bottom is considered as a plane and is meshed into small grids. The tooth is also meshed into grids (single elements). *See Present Application, Page 12, lines 10-11.*

F. ***incrementally rotating the bit;***

1. After having the single element force model, the next step is to determine the interaction between inserts and the formation drilled. This step involves the

determination of the tooth kinematics (local) from the bit and cone kinematics (global) as described below.

(1) The bit kinematics is described by bit rotation speed, Ω=RPM (revolutions per minute), and the rate of penetration, ROP. Both RPM and ROP may be considered as constant or as function with time.

(2) The cone kinematics is described by cone rotational speed. Each cone may have its own speed. The initial value is calculated from the bit geometric parameters or just estimated from experiment. In the calculation the cone speed may be changed based on the torque acting on the cone.

(3) At the initial time, t0, the hole bottom is considered as a plane and is meshed into small grids. The tooth is also meshed into grids (single elements). At any time t, the position of a tooth in space is fully determined. *See Present Application, Page 11, line 30 through Page 12, line 12.*

G. ***repeating the calculating of the crater parameters and the bottomhole geometry based on calculated roller cone rotation speed and geometrical location with respect to rotation of the bit about its axis.***

1. See Paragraph VI(B)(1) above. *See Present Application, Page 12, lines 11-14.*

XXVIII. Support for Claim 28

A. ***The method of Claim 27 wherein the predetermined relationship is determined by laboratory experiment.***

1. See Paragraph III(A)(1) above. See Present Application 11, lines 7-24.